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WEIGHT ESTIMATE OF CANTILEVER MONOPLANE WINGS OF CORRUGATED ALUMINUM ALLOY BOX-TYPE CONSTRUCTION FOR PURSUIT, ATTACK, TWIN-ENGINED OBSERVATION AND TRANSPORT AIRPLANES

(AIRPLANE BRANCH REPORT)

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WEIGHT ESTIMATE OF CANTILEVER MONOPLANE WINGS OF CORRUGATED ALUMINUM ALLOY BOX-TYPE CONSTRUCTION FOR PURSUIT, ATTACK, TWIN-ENGINED OBSERVATION, AND TRANSPORT AIRPLANES

(Prepared by Charles G. Brown, Matériel Division, Air Corps, Wright Field, Dayton, Ohio, June 12, 1931)

OBJECT

The object of this study was to determine, as closely as a rough design would permit, the unit weight at which metal wings of box construction could be built for pursuit, attack, twin-engined observation, and transport airplanes.

DESIGN FEATURES AND CONDITIONS

The principal features of construction to be used in the design of these wings are:

(*a*) That a corrugated flange shall extend across the upper chord between two thin metal webs. This flange shall carry the compression due to high and low incidence loadings. The pitch of the corrugations shall be 2½ inches and the depth three-fourths inch.

(*b*) Heavy flange angles shall be used for joining the webs and upper corrugated flange.

(*c*) The webs shall be unlightened flat sheets of aluminum alloy stiffened with vertical angle members, to be used in pairs, one on either side of the web. These stiffeners shall act also as a means of attaching the bulkheads to the webs of the box portion of the wing. Although the weight estimate will be made on the basis of unlightened webs, it is felt that lightened webs, of the double Pratt truss type, having plain flat tension members, can be used advantageously, with a probable saving in weight where sections are deep. Any loss in rigidity due to using this type of web will be small.

(*d*) The upper covering, from front web to trailing edge, shall be of corrugated aluminum alloy sheet of 1¼-inch pitch and ⅜-inch depth. This material will support the corrugated material of the box section to such an extent that a coefficient of fixity of three may be used in the design of the flanges. It will also reduce the material that must be put into ribs or bulkheads to the rear of the rear spar.

(*e*) The lower skin shall be of flat sheet stock and will be considered as a part of the tension flange of the box section of the wing in the high and low incidence conditions. The tension in this lower flange may be considered as tapering from the tension at the webs to zero at the leading and trailing edges; hence any splices outside of the box portion must be designed to carry tension loads. The flat skin will extend from the front webs on the upper chord, around the wing to the trailing edge.

(*f*) Ribs of a double Pratt truss type having flat tension members will be considered. The lower flange of the ribs will be made sufficiently heavy to resist the compression between front and rear webs due to chord loads. This flange will be well supported by the lower skin.

(*g*) The compression loads in the lower flange in the inverted flight condition shall be resisted entirely by the flange angles at the webs, no corrugated material being provided on the lower chord. The flat skin shall be considered as having no resistance to compressive loads.

(*h*) For the purposes of this study it will be considered sufficiently accurate to assume a uniform distribution of stress across the corrugated flange.

(*i*) The position of the airfoil vector in the nose-dive condition will be that for the Gottingen 398 airfoil, as shown in Serial No. 3293, Air Forces and Moments Acting on Airplanes, for the pursuit and attack wings. The torque at the wing root will be that due to this extreme position of the airfoil vector.

(*j*) Studies of the strength of corrugated aluminum alloy sheets in shear being conducted at this date indicate that the flange material provided in the upper flange will be sufficient to resist the shears due to nose-dive torque.

(*k*) The wings shall taper both in planform and thickness ratio, and shall be similar in planform.

(*l*) A modified USA 35 airfoil having a root thickness ratio of 18.46 per cent and a tip thickness ratio of 11.76 per cent will be used. The center of pressure location for high incidence and inverted flight will be taken at 31 per cent chord; for low incidence at 52 per cent chord. The chord to beam ratio for high incidence shall be taken as −0.158; for low incidence +0.150; and for inverted flight, zero.

(*m*) In computing the shears and moments, an estimated dead weight of 1.75 pounds per square foot shall be used. This will be assumed to be distributed uniformly over the equivalent wing area.

(*n*) The computed weight of the wings will be increased 10 per cent to allow for all items not actually included in the weight estimate.

Note

Studies completed after this report had been completed indicate that the method of analysis used is applicable only to a rough design or approximation. The stresses developed in a wing structure of the type considered have been found to vary in accordance with the flexure formula.

$$f=M\frac{c}{I}$$

The moment of inertia I should be determined by considering only the box portion unless the other por-

tions of the wing are sufficiently reinforced to carry high stresses.

For a later and more complete discussion of stresses in wings of the type herein considered see—

Serial 3227, A. D. M. 1110.—Column Properties of Corrugated Aluminum Alloy Sheet.

Serial 3415, A. D. M. 1168.—Static Test of Matériel Division 27-foot Metal Cantilever Wing and Driggs Dart 27-foot Wood Cantilever Wing.

Serial 3501, A. D. M. 1169.—Static Test and Stress Distribution Studies of the Matériel Division 55-foot Metal Wing.

Serial ——, A. D. M. 1203.—Shear Strength of Corrugated Aluminum Alloy Sheet.

Serial ——, A. D. M. 1207.—Structural Design of the Matériel Division Y1C–12 Metal Wing.

Summary of estimated wing weights

Wing	Pursuit	Attack	Twin-engined observation	Transport
Span........feet..	32	46⅓	64	79
Root chord........inches..	72	108	144	170
Wing area........square feet..	160	304	578	854
Gross weight of airplane........pounds..	2,200	5,000	8,000	12,500
Load factor, H. I........	12	8.5	8.5	5.5
Load factor, L. I........	6.5	5.5	5.5	3.5
Load factor, I. F........	4	3.5	3.5	2.5
Estimated dead weight of wing........	1.75	1.75	1.75	1.75
Computed weight........	1.71	1.79	1.42	1.42
1.10 × computed weight........	1.88	1.97	1.56	1.56

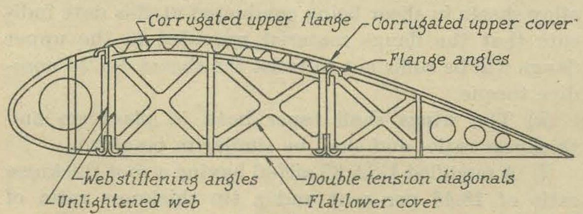

FIGURE 1.—Typical wing cross section

Angle sections

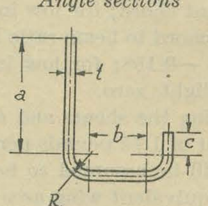

FIGURE 2

$$\text{Area} = [a \pm b + c + \pi R]\, t$$

Section No.	a	b	c	R	t	Area	Where used
1	1⅜	5⁄16	----	¼	0.094	0.231	Pursuit upper flange.
2	1⅜	5⁄16	----	¼	.125	.310	Do.
3	1⅜	5⁄16	----	¼	.064	.157	
4	1¼	¼	----	¼	.094	.214	Pursuit lower flange.
5	1⅛	1⁄16	----	¼	.094	.184	Do.
6	1⅛	1⁄16	----	¼	.050	.098	Do.
7	1¼	¼	----	¼	.050	.114	Do.
8	1⅝	½	----	¼	.125	.380	Attack lower flange.
9	1½	¼	----	¼	.125	.316	Do.
10	1⅝	½	----	¼	.064	.190	Do.
11	1⅛	1⁄16	----	¼	.050	.098	Do.
12	1¼	¼	----	¼	.064	.146	Do.
13	1½	½	----	5⁄16	.156	.470	
14	1⅜	⅝	----	¼	.125	.345	
15	2 3⁄16	⅝	¼	5⁄16	.156	.630	
16	2⅛	7⁄16	----	¼	.093	.313	
17	2⅛	7⁄16	¼	¼	.093	.325	
18	2⅛	7⁄16	¼	¼	.125	.432	
19	2 3⁄16	⅝	½	¼	.156	.680	

DESIGN OF METAL WINGS

Types of wings

I. PURSUIT (SK–15978)

Span........ 32 feet.
Root chord........ 72 inches.
Wing area........ 160 square feet.
Gross weight, airplane........ 2,200 pounds.
Factors, H. I........ 12.
Factors, L. I........ 6.5.
Factors, I. F........ 4.0.
Estimated weight, 1.56–1.75 pounds per square foot.

II. ATTACK (XA–7)

Span........ 46 feet, 4 inches.
Root chord........ 108 inches.
Wing area........ 304 square feet.
Gross weight, airplane........ 5,000 pound.
Factors, H. I........ 8.5.
Factors, L. I........ 5.5.
Factors, I. F........ 3.5.
Estimated weight, 1.93–2.2 pounds per square foot.

III. TWIN-ENGINED OBSERVATION—FAST DAY BOMBER

Span........ 64 feet.
Root chord........ 12 feet.
Wing area........ 578 square feet.
Gross weight, airplane........ 8,000 pounds.
Factors, H. I........ 8.5.
Factors, L. I........ 5.5.
Factors, I. F........ 3.5.
Estimated weight, 1.75 pounds per square foot.

XO–27—TWIN-ENGINED OBSERVATION

Gross weight........ 7,950 pounds (say 8,000 pounds).
Wing loading........ 13.75 pounds per square foot.
Total area........ 578 square feet.
Effective area........ 471 square feet.
Useful area........ 558.4 square feet.
Root chord........ 144 inches.
Tip chord........
Span........ 64 feet.
Factors........ 8.5; 5.5; 3.

FORD 4–AT

Gross weight........ 9,300 pounds.
Total wing area........ 749 square feet.
Root chord........ 154 inches.
Tip chord........ 92 inches.
Span........ 68 feet.
Effective area........ 648 square feet.

FOKKER F–XA

Gross weight........ 12,500 pounds.
Wing area........ 854 square feet.
Wing loading........ 14.7 pounds per square foot.
Useful area........ 785 square feet.
Span........ 791 feet.
Factors........ 4.5; 3; 1.8.
Root chord........ 170 inches.

I. PURSUIT WING

Thickness ratio chord, CD$=\frac{30}{152}\times(18.46-11.76)+11.76=13.08$ per cent chord.

Thickness ratio chord, AB$=11.76-\frac{25}{152}(18.46-11.76)=10.16$ per cent chord.

Equivalent chord, CD$'=\frac{13.08}{18.46}\times 55=39$ inches.

Equivalent chord, AB$'=\frac{10.16}{18.46}\times 30=16.5$ inches.

Area, AB$'$CD$'=\frac{(165+39)\times 55}{2}=$ 1,525 square inches.

Area, CD$'$EF $=\left(\frac{39+72}{2}\right)\times 122=6{,}882$ square inches.

Total ---------- 8,407 square inches.

Gross weight of airplane, 2,200 pounds.

Total wing area, 160 square feet.

Estimated wing weight, $160\times 1.75=280$ pounds.

Computation of loading over equivalent wing—

$$6882W+0.915\times 1525W=1{,}100 \text{ pounds}-140.$$

$$8278W=0.961 \text{ pound.}$$

$$W=0.116 \text{ pound per square inch.}$$

The factor 0.915 represents the mean loading over the tip portion of the wing. This is a computed value and is slightly greater than the 0.90 prescribed for use with a loading which tapers to 0.8 at the extreme tip.

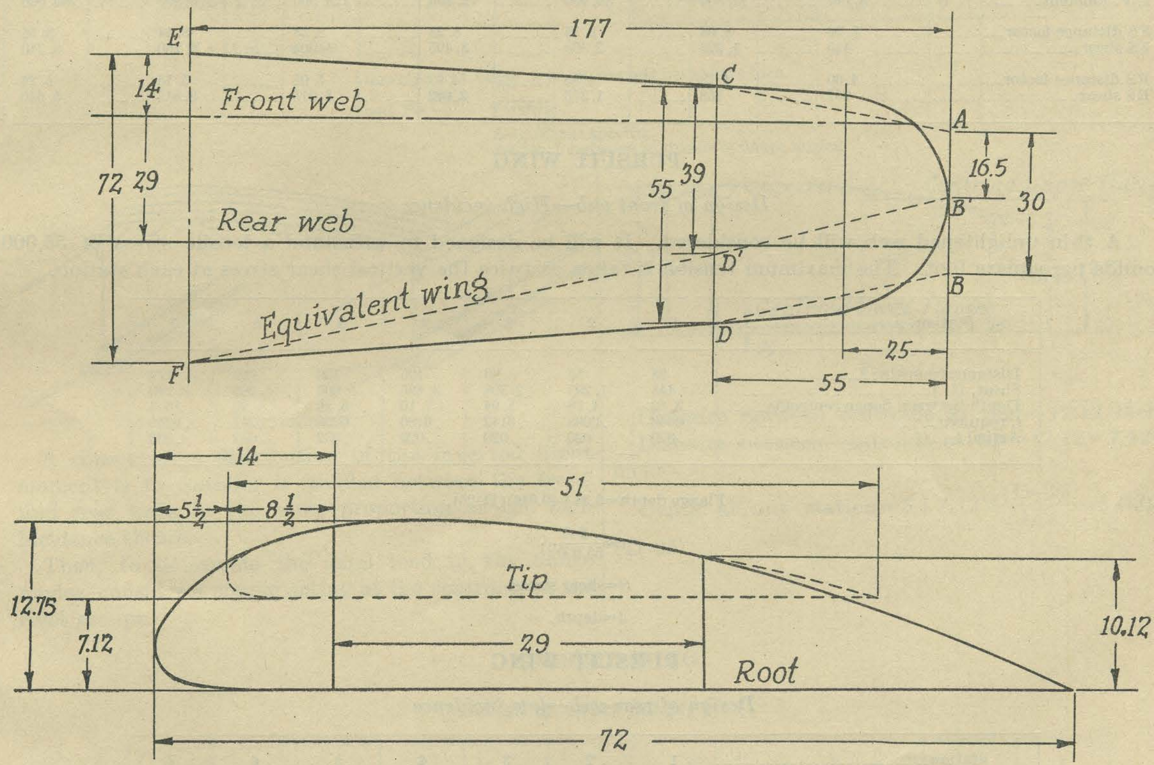

FIGURE 3.—Pursuit wing.

PURSUIT WING

Load distribution factors

Station	1	2	3	4	5	6	7
Distance from tip	28	55	80	105	130	150	177
Actual chord	51.4	55	58.6	62	65.5	68.3	72
Distance LE–CP 31 per cent	15.90	17.08	18.20	19.20	20.30	21.20	22.30
Distance LE–CP 52 per cent	26.70	28.70	30.50	32.20	34.00	35.50	37.40
Distance LE–FS	6.16	7.58	8.89	10.21	11.52	12.58	14.00
Distance LE–RS	35.16	36.58	37.89	39.21	40.52	41.58	43.00
Distance 31 per cent–RS	19.26	19.50	19.69	20.01	20.22	20.38	20.70
Distance 52 per cent–FS	20.54	21.12	21.61	21.99	22.48	22.92	23.40
FS distance factor, H. I. and I. F	0.664	0.673	0.679	0.690	0.698	0.703	0.714
RS distance factor, L. E	0.709	0.728	0.746	0.759	0.776	0.790	0.807
FS distance factor×LF, H. I	7.96	8.08	8.15	8.28	8.38	8.44	8.56
RS distance factor×LF, L. I	4.60	4.73	4.85	4.93	5.05	5.13	5.24

Distance from leading edge to front spar=6+0.0526 (D–25)

PURSUIT WING

Shears and moments

Station	0		1		2		3		4		5		6		7
Distance from tip	0		28		55		80		105		130		150		177
Chord, equivalent wing	16.5		28		39		45.6		52.5		59		67.3		72
Distance between stations, X		28		27		25		25		25		20		27	
Running load, pounds per inch	.956		2.95		4.52		5.3		6.09		6.85		7.81		8.35
Mean load between stations		2.04		3.85		4.91		5.70		6.46		7.33		8.08	
Load between stations, w		56		104		123		142.5		61.6		146.6		218	
Total unit shear	0		56		160		283		422.5		597.1		743.7		961.7
Moment SX	0		0		1,511		4,000		7,080		10,560		11,930		20,100
Moment $w\frac{X^2}{2}$		784		1,405		1,538		1,780		2,020		1,466		2,940	
Total unit moment	0		784		3,700		9,238		18,098		30,678		44,074		67,114
H. I. moment	0		9,400		44,400		110,900		216,000		368,000		530,000		804,000
I. F. moment	0		3,140		14,800		36,950		72,450		126,900		176,800		269,000
FS distance factor			7.96		8.08		8.15		8.28		8.38		8.44		8.56
FS shear			445		1,293		2,308		3,495		5,000		6,260		8,240
RS distance factor			4.60		4.73		4.85		4.93		5.05		5.13		5.24
RS shear			257		758		1,373		2,082		3,015		3,815		5,040

PURSUIT WING

Design of front web—High incidence

A thin unlightened web will be considered. It will be designed to withstand a tensile stress of 55,000 pounds per square foot. The maximum tension is taken as twice the vertical shear stress at each station.

Station	1	2	3	4	5	6	7
Distance from tip	28	55	80	105	130	150	177
Shear, H. I.	445	1,293	2,308	3,495	5,000	6,260	8,240
Depth between flange centroids	3.52	4.78	5.94	7.10	8.26	9.20	10.5
t, required	.0046	.0098	.0142	.0180	.0220	.0247	.0285
Actual t	.020	.020	.020	.020	.032	.032	.032

Flange depth=3.38+(0.046)(D−25).

$$t=\frac{2S}{55{,}000\,d}.$$

S=shear stress.

d=depth.

PURSUIT WING

Design of rear web—low incidence

Station	1	2	3	4	5	6	7
Distance from tip	28	55	80	105	130	150	177
Shear, L. I.	257	758	1,373	2,082	3,015	3,815	5,040
Distance between flange centroids	1.14	2.40	3.56	4.72	5.88	6.81	8.12
t, required	.0106	.0115	.0141	.0161	.0186	.0203	.0226
Actual t	.016	.016	.016	.024	.024	.024	.024

depth=1+0.0465 (D−25).

$$t\text{, required}=\frac{2S}{55{,}000\,d}.$$

S=shear stress in. lbs. per sq. in.
d=depth.

PURSUIT WING

Design of web stiffeners

FRONT WEB

Station	1	2	3	4	5	6	7
Shear, F ... pounds	445	1,293	2,308	3,495	5,000	6,260	8,240
Depth between centroids, d ... inches	3.52	4.78	5.94	7.10	8.26	9.20	10.5
Spacing, L ... do	4	4	4	3.75	3.75	3.75	3.50
Load, P ... pounds	505	1,080	1,555	1,845	2,270	2,550	2,745
Area required ... square inches	.028	.054	.078	.093	.113	.128	.137
Gage of stiffener [1]	.020	.020	.020	.020	.024	.024	.032
Stiffener area	.120	.120	.120	.120	.144	.144	.192

REAR WEB

Station	1	2	3	4	5	6	7
Shear, F ... pounds	257	758	1,373	2,082	3,015	3,815	5,040
Depth between centroids, d ... inches	1.14	2.40	3.56	4.72	5.88	6.81	8.12
Spacing, L ... do	4	4	4	3.75	3.75	3.75	3.50
Load, P ... pounds	900	1,265	1,543	1,653	1,983	2,100	2,170
Area required ... square inches	.045	.063	.077	.083	.094	.105	.106
Gage of stiffener [1]	.020	.020	.020	.020	.020	.020	.020
Stiffener area	.120	.120	.120	.120	.120	.120	.120

[1] ¾ x ¾ plain angles.

Allowable P/A taken at 20,000 pounds per square inch.

Load $P=\frac{FL}{d}$ F=shear.
L=stiffener spacing.
d=depth between centroids of flange angles.

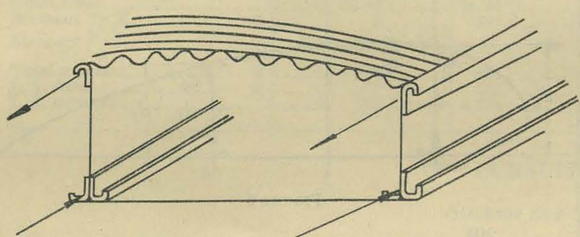

FIGURE 4

A conservative distribution of the inverted flight moment is to consider it divided between the front and rear webs in the same proportion as the high incidence shears.

Then, to determine the axial load in the flange angles, consider a couple acting at the centroids of the rivet groups.

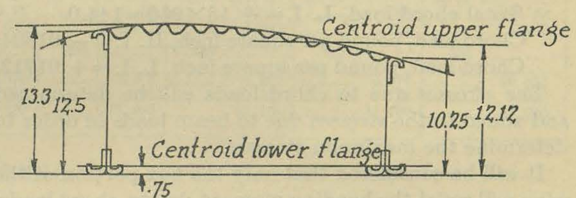

FIGURE 5

Distance between centroids at root=12.12 inches.

Distance between centroids at tip=12.12−7.12=5 inches.

$$\text{Depth at any station}=5+7.12\times\frac{(D-25)}{152}=5+.0465\ (D-25).$$

PURSUIT WING

Design of upper flange, H. I.

Station	1	2	3	4	5	6	7
Moment, H. I. ... inch-pound	9,400	44,400	110,900	216,000	368,000	530,000	804,000
Depth between centroids ... inches	5.14	6.40	7.56	8.72	9.89	10.82	12.12
Axial load ... pounds	1,830	6,940	14,630	24,660	37,250	48,900	66,300
Rib spacing ... inches	16	16	16	15	15	15	14
L/ρ covering	56	----------	60	56	56	56	52
Allowable P/A cover	29,400	----------	20,000	25,000	29,000	33,000	36,000
Total area required	----------	----------	.732	1.986	1.285	1.480	1.842
Net area, covering	----------	----------	.420	.523	.822	1.017	1.379
Gage required	----------	----------	.011	.0146	.023	.0285	.0386
R/t	----------	----------	42	34	27	21	13.5
Allowable P/A buckling	----------	----------	23,000	25,000	29,000	33,000	36,000
Actual gage, estimated	----------	----------	.016	.020	.025	.032	.040
Flange angle section ... No.	3	3	3	1	1	1	1
Area ... square inch	.314	.314	.314	.462	.462	.462	.462

2½-inch pitch, ¾-inch depth corrugations—R=.95 D=.675 inch. Design stresses from A. D. M. 1110, C=3.
ρ=.359 D=.269 inch. Allowable stresses in flange angles taken same as those in corrugated flanges. Upper flange angle area=.463 square inch.

$$\text{Depth between centroids}=5+\frac{7.12}{152}\ (D-25)$$

$$t\ \text{required}=\frac{A}{29\times1.23}=\frac{A}{36}$$

PURSUIT WING

Design of lower flange, I. F.

Station	1	2	3	4	5	6	7
Total moment	3,140	14,800	36,950	72,450	126,900	176,800	269,000
FS distance factor	.664	.673	.679	.690	.698	.703	.714
FS moment	2,085	9,960	25,200	49,950	88,600	124,000	192,000
RS moment	1,055	4,840	11,750	22,500	38,300	52,800	77,000
Distance between centroids, FS	3.52	4.78	5.94	7.10	8.26	9.20	10.50
Distance between centroids, RS	1.14	2.40	3.56	4.72	5.88	6.81	8.12
Axial load, FS	593	2,080	5,100	7,040	10,600	13,480	18,300
Axial load, RS	920	2,020	3,300	4,770	6,520	7,760	9,490
	Allowable P/A taken as 25,000 pounds per square inch						
Area required, FS	.023	.083	.204	.281	.424	.540	.732
Area required, RS	.037	.081	.132	.188	.250	.310	.318
Actual section, FS [1]	1 #7	1 #7	{ 1 #4 1 #7	1 #4 1 #7	2 #4 1 #5	2 #4 1 #5	2 #4 2 #5
Area, square inch	.114	.114	.328	.328	.612	.612	.793
Actual section, RS [1]	1 #7	1 #7	1 #4	1 #4	{ 1 #4 1 #7	1 #4 1 #7 }	2 #4
Area, square inch	.114	.114	.214	.214	.328	.328	.428

[1] See table under Figure 2, p. 2.

Investigation of effect of chord loads on total stresses.

Chord loads:

C/B, H. I. = −.158.

C/B, L. I. = +.15.

Total chord load, H. I. = −.158×960 = −151.68 pounds.

Total chord load, L. I. = +.15×960 = 144.0.

Chord load, pound per square inch, H. I. = −.01804.

Chord load, pound per square inch, L. I. = +.01712.

The stresses due to chord loads will be determined and added to the stresses due to beam loads in order to determine the maximum stresses.

It will be considered that only the box portion of the wing will resist the bending moment due to chord loads.

The moment of inertia of the box section about its minor axis will be computed and the stresses at the corners computed from the expression

$$S=\frac{My}{I}$$

S = tensile or compressive stress.

y = distance from neutral axis to outermost fiber.

I = moment of inertia of section.

M = applied moment.

PURSUIT WING

Determination of moment of inertia of box section about vertical axis

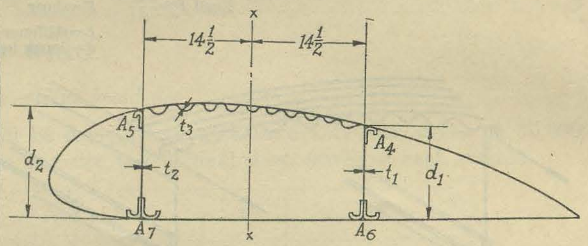

FIGURE 6

$$I_{x-x}=\frac{29^3}{12}[1.23t+.028]\times(14.5)^2[d_1t_1+d_2t_2+A_4+A_5+A_6+A_7]=2030[1.23t+.028]211[d_1t_1+d_2t_2+\Sigma A_F]$$

The neutral axis will be considered at a point midway between the flanges. This will give the least moment of inertia of the section and the error involved is small.

PURSUIT WING

Computation of moment inertia about short axis

Station	1	2	3	4	5	6	7
A_7, rear	0.187	0.187	0.187	0.374	0.374	0.374	0.374
A_6, front	0.187	0.187	0.374	0.374	0.561	0.561	0.748
A_5, rear	0.232	0.232	0.232	0.232	0.232	0.232	0 232
A_4, front	0.232	0.232	0.232	0.232	0.232	0.232	0.232
d_1t_1, rear	0.050	0.071	0.089	0.163	0.189	0.212	0.243
d_2t_2, front	0.111	0.136	0.158	0.182	0.329	0.358	0.400
ΣA	0.999	1.045	1.272	1.557	1.917	1.969	2.229
211 ΣA	210	220	268	328	404	415	470
t_3	0.016	0.016	0.020	0.020	0.032	0.032	0.040
(1.23 t_3+.028)	.0477	.0477	.0526	.0526	.0673	.0673	.0772
2030 (1.23 t_3+0.28)	97	97	107	107	137	137	157
I	307	317	375	435	541	552	627
Y/I (Y=15½)	0.051	0.049	.0413	.0357	.0286	.0281	.0247

PURSUIT WING

Chord load shears and moments

HIGH INCIDENCE

Station	0		1		2		3		4		5		6		7
Distance from tip	0		28		55		80		105		130		150		177
Distance between station, X		28		27		25		25		25		20		27	
Chord equivalent wing	16.5		28		39		45.6		52.5		59		67.3		72
Running load, pounds per inch	.298		0.505		0.685		0.842		0.930		1.065		1.214		1.30
Mean load between station		0.402		0.595		0.763		0.886		0.997		1.139		1.257	
Load between station, W		11.28		16.07		19.08		22.20		24.90		22.80		33.90	
Total shear			11.28		27.35		46.43		68.63		93.53		116.33		150.23
Moment SX	0		0		304		658		1,160		1,715		1,875		3,140
Moment $\frac{WX}{2}$		158		217		238		277		311		228		458	
Total moment	0		158		679		1,575		2,962		4,988		7,091		10,689
H. I. shear	0		135		328		545		812		1,125		1,396		1,805
H. I. moment			1,895		8,150		18,900		35,600		59,800		85,000		128,100

LOW INCIDENCE

Station	0		1		2		3		4		5		6		7
Running load, pounds per inch	.283		0.490		0.669		0.781		0.900		0.995		1.152		1.233
Mean load between station		0.387		0.579		0.725		0.841		0.948		1.073		1.192	
Load between station, W		10.83		15.62		18.13		21.05		24.70		21.50		32.20	
Total shear			10.83		26.45		44.58		65.63		90.33		111.83		144.03
Moment $S \times X$	0		0		292		637		1,117		1,642		1,807		3,015
Moment $\frac{WX}{2}$		152		211		227		264		309		215		435	
Total moment	0		152		656		1,520		2,901		4,852		6,874		10,324
L. I. shear	0		75		172		290		427		587		775		936
L. I. moment			989		4,270		9,890		18,890		31,550		44,700		67,200

PURSUIT WING

Stresses due to chord loads

Station	1	2	3	4	5	6	7
Total area upper flange	1.065	1.065	1.215	1.215	1.665	1.665	1.969
H. I. axial load	1,830	6,940	14,630	24,660	37,250	48,900	66,300
H. I. P/A	1,720	6,520	12,050	20,300	22,400	29,400	33,700
Y/I section	.051	0.049	0.041	0.036	0.029	0.028	0.025
Chord moment, H. I.	1,895	8,150	18,900	35,600	59,800	85,000	128,000
P/A due to chord load	92	400	775	1,280	1,740	2,380	3,200
Total P/A F. U. flange, H. I.	1,812	6,920	12,830	21,580	24,140	31,780	36,900
Allowable			23,000	25,000	29,000	33,000	36,000
L. I. moment	5,080	24,000	59,900	117,600	199,300	286,500	436,000
Depths between centroids	5.14	6.40	7.56	8.72	9.89	10.82	12.12
L. I. axial load	990	3,750	7,920	13,480	20,150	26,500	36,300
L. I. P/A							18,450
Chord moment, L. I.	989	4,270	9,890	18,890	31,550	44,700	67,200
P/A chord loads			Not critical				1,630
Total stress R. U. flange							20,080

(Recommended that an additional section of flange angle be added to the front upper flange between stations 6 and 6′.)

PURSUIT WING

Investigation of nose-dive condition

Assumed terminal velocity = 350 miles per hour.

Assumed K_r = resultant airfoil vector = −.000039 (approximately that of Gott. 398) when K_r = .000.

Distance from elastic axis to wing vector approximately 5.5 mean chord lengths.

The root moment will be calculated in terms of the mean aerodynamic chord.

$Q_r = K_r A V^2 \times d.$

K_r = resultant airfoil vector = −.000039.

A = one-half wing area = 80 square feet.

V = velocity of dive = 350 miles per hour.

d = distance from elastic axis to vector = 5.5×61.5.

$Q_r = .000039 \times 80 \times 350 \times 5.5 \times 61.5 = 129{,}500$ inch-pound acting at the root of the wing.

Area of box section = $12.12 \times 29 = 352$ square inches, approximately.

The shear stresses due to torque will be computed by the expression

$$S=\frac{Q}{2AT}$$

S = shear stress, pounds per square inch.
Q = torque, inch-pound.
A = cross section at area of section considered.
t = skin thickness at section considered.

PURSUIT WING

Nose-dive condition

UPPER COVERING

t = sum of thicknesses of flange and outer corrugated sheet $=0.040+0.012=0.052$ inch.

$$S_{U.F.}=\frac{129{,}500}{2\times 352\times 0.052}=3{,}525 \text{ pounds per square inch}$$

LOWER COVERING

Here the principal stress will be tension and will be double the value of the shear stress.

$$t=0.014$$

$$T_{L.F.}=\frac{129{,}500}{352\times 0.014}=36{,}800 \text{ pounds per square inch.}$$

The allowable shearing stress on the upper corrugated flange will be about 10,000 pounds per square inch, hence the stresses due to torque are negligible for this member.

The allowable stress for the lower flange will be its ultimate tensile stress of 55,000 pounds per square inch, hence it is satisfactory.

PURSUIT WING

Weight estimate (one-half wing)

Item	Amount	Section and area	Unit weight	Total weight
			Pounds per cubic inch	*Pounds*
Upper flange angles	190 inches	No. 1 0.231	0.1011	4.5
	180 inches	No. 3 0.157	.1011	2.9
Lower flange angles	330 inches	No. 4 0.214	.1011	7.2
	75 inches	No. 5 0.184	.1011	1.4
	237 inches	No. 7 0.114	.1011	2.7
Webs:			*Pounds per square inch*	
Front	120 inches	0.020 x 8.60	.00202	2.1
	70 inches	0.032 x 11.1	.00324	2.5
Rear	95 inches	0.016 x 4.6	.00162	.7
	95 inches	0.024 x 8.13	.00242	1.9
Stiffeners:				
Front web—				
1	24 at 12 inches	t=.024	.00486	1.4
2	48 at 10 inches	t=.024	.00363	1.75
3	96 at 8 inches	t=.020	.00303	2.23
Rear web	11 x 16 at 6½ inches	t=.020	.00303	3.5
Total				34.8
Corrugated upper flange:				
1	29 inches	Flat width 36 inches t=.040	.00404	4.22
2	44 inches	Flat width 36 inches t=.032	.00324	5.14
3	46 inches	Flat width 36 inches t=.020	.00202	3.35
4	51 inches	Flat width 36 inches t=.016	.00162	3.00
Total, corrugated flange				15.71
Corrugated covering, front web to trailing edge:				
1	58 inches	Flat width 36 inches t=.012	.00121	2.5
2	56 inches	Flat width 36 inches t=.012	.00121	2.4
3	53 inches	Flat width 36 inches t=.012	.00121	2.3
4	50 inches	Flat width 36 inches t=.012	.00121	2.2
5	48 inches	Flat width 50 inches t=.012	.00121	2.9
Total				12.3
Leading edge	166 inches	Width 25 inches t=.020	.00202	8.4
Spar, L. F.	90 inches	Width 30 inches t=.014	.00141	3.8
Spar	77 inches	Width 30 inches t=.014	.001413	3.3
Trailing edge	166 inches	Width 22 inches t=.014	.001413	5.2
Total, lower covering				20.7
Wing tip	3,000 square inches, approximately		.001413	4.3
Control rods, ail, cranks, etc				6
Aileron horn, spar and false spar, hinges (aileron cover included in main cover)				4
Miscellaneous fittings, wiring, etc				12
Total				22

PURSUIT WING

Total weight (one-half wing) less ribs .... 109.8 pounds.
Ribs at 25 per cent of weight less ribs .... 27 pounds.

Total weight, one-half wing .... 136.8 pounds.
Area, one-half wing .... 80 square feet.
Dead weight of wing .... 1.71 pounds per square foot.
1.10 × dead weight .... 1.88 pounds per square foot.

II. ATTACK WING

Gross weight of airplane	5,000 pounds.
Wing area, total	304 square feet.
Estimated unit weight of wing	1.75 pounds per square foot.
Estimated total wing weight	532 pounds.
Weight less wings	4,468 pounds.

Thickness ratio chord, $AB=11.76-\frac{31}{231}(18.46-11.76)=11.76-0.87=10.89$.

Thickness ratio chord, $EF=11.76+\frac{45}{231}(18.46-11.76)=11.76+1.30=13.06$.

Equivalent chord, $A'B'=\frac{10.89}{18.46}\times 47.5=28.0$ inches.

Equivalent chord, $E'F'=\frac{13.06}{18.46}\times 76=53.75$ inches.

Area, $GHEF'=\frac{108+53.75}{2}\times 186=$ 15,043 square inches.

Area, $EF'AB'=\frac{28+53.75}{2}\times 76=$ 3,106 square inches.

Total 18,149 square inches.

Computation of loading—

$$15{,}043W+0.915\times 3106W=2{,}234 \text{ pounds.}$$
$$15{,}034W+2842W=2{,}234 \text{ pounds.}$$
$$17{,}885W=2{,}234 \text{ pounds.}$$
$$W=0.1249 \text{ pounds per square inch.}$$

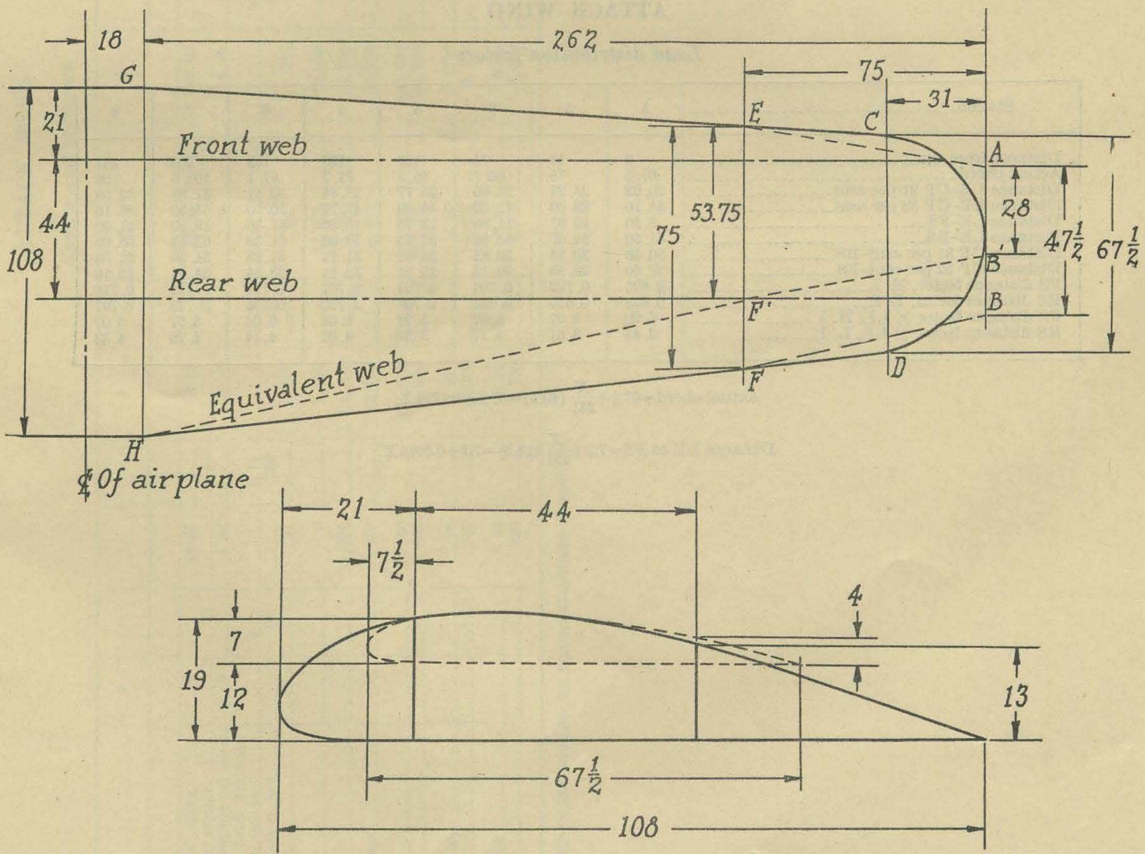

FIGURE 7.—Attack wing

ATTACK WING

Airfoil ordinates

Per cent chord	Root					Tip				
	Chord=108 inches					Chord=67½ inches				
	Distance along chord	Ordinates				Distance along chord	Ordinates			
		Upper		Lower			Upper		Lower	
		Per cent	Inches	Per cent	Inches		Per cent	Inches	Per cent	Inches
0	0	4.33	4.67	4.33	4.67	00	2.76	1.86	2.76	1.86
1¼	1.4	8.09	8.73	1.62	1.75	0.85	5.15	3.48	1.03	0.69
2½	2.7	9.54	10.30	1.00	1.08	1.70	6.11	4.13	0.63	0.42
5	5.4	11.81	12.76	0.46	0.50	3.37	7.52	5.07	0.28	0.19
7½	8.1	13.58	14.65	0.22	0.24	5.06	8.65	5.85	0.14	0.09
10	10.8	14.85	16.02	0.10	0.11	6.75	9.45	6.38	0.07	0.05
15	16.2	16.60	17.91	0	0	10.12	10.56	7.12	0	0
20	21.6	17.73	19.15			13.50	11.28	7.60		
30	32.4	18.46	19.90			20.25	11.76	7.84		
40	43.2	17.89	19.30			27.00	11.42	7.71		
50	54.0	16.21	17.50			33.75	10.33	6.60		
60	64.8	13.83	14.92			40.50	8.81	5.95		
70	75.6	11.11	12.00			47.25	7.08	4.78		
80	86.4	7.88	8.50			54.00	5.02	3.39		
90	97.2	4.31	4.65			60.70	2.72	1.84		
95	102.5	2.39	2.58			64.10	1.50	1.00		
100	108.0	0.43	0.46			67.50	0.25	0.17		

ATTACK WING

Load distribution factors

Station	1	2	3	4	5	6	7	8
Distance from tip	0	44	75	107	138	169	200	231
Actual chord	67.5	75	80.7	86.3	91.7	97.1	102.6	108
Distance LE–CP 31 per cent	20.92	23.23	25.00	26.77	28.44	30.11	31.80	33.50
Distance LE–CP 52 per cent	35.10	39.00	42.00	44.90	47.70	50.50	53.30	56.10
Distance LE–FS	7.50	10.07	11.88	13.75	15.56	17.36	19.19	21.00
Distance LE–RS	51.50	54.07	55.88	57.75	59.56	61.36	63.19	65.00
Distance CP 31 per cent–RS	30.58	30.84	30.88	30.98	31.12	31.25	31.39	31.50
Distance CP 52 per cent–FS	27.60	28.93	30.12	31.15	32.14	33.14	34.11	35.10
FS distance factor, H. I.	0.695	0.702	0.703	0.704	0.707	0.711	0.714	0.716
RS distance factor, L. I.	0.628	0.657	0.685	0.708	0.730	0.753	0.775	0.797
FS distance factor × LF, H. I.	5.90	5.97	5.97	5.98	6.01	6.04	6.07	6.07
RS distance factor × LF, L. I.	3.45	3.61	3.77	3.89	4.02	4.14	4.26	4.38

$$\text{Actual chord}=67.5+\frac{X}{231}(40.5)=67.5+0.1754X.$$

$$\text{Distance LE to FS}=7.5+\frac{X}{231}(13.5)=7.5+0.0584X.$$

ATTACK WING

Shears and moments

Station	0		1		2		3		4		5		6		7		8
Distance from tip																	
Chord, equivalent, wing	28		38.65		53.75		63.04		72.00		81.00		90.00		99.00		108.00
Distance between station, X		31		44		32		31		31		31		31		31	
Running load, pounds per inch	3.49		4.83		6.71		7.86		8.99		10.10		11.24		12.35		13.48
Mean running load between station, pounds per inch		4.16		5.77		7.28		8.42		9.54		10.66		11.78		12.91	
Load between station, w [1]		127		250		230		257		291		325		360		394	
Total shear, S			127		377		607		864		1,155		1,480		1,840		2,234
Moment SX			0		5,690		12,070		18,820		26,800		35,800		45,900		57,000
Moment $w \frac{X}{2}$			1,970		5,500		3,680		3,980		4,510		5,040		5,580		6,110
Total unit moment			1,970		13,160		28,910		51,710		83,020		123,860		175,340		238,450
H. I. moment			16,750		111,800		247,500		440,000		705,500		1,051,000		1,490,000		2,030,000
I. F. moment			6,900		46,000		101,200		181,000		291,000		433,000		614,000		835,000
FS distance factor			5.90		5.97		5.97		5.98		6.01		6.04		6.07		6.07
FS shear, H. I.			750		2,250		3,622		5,160		6,945		8,930		11,180		13,560
RS distance factor			3.45		3.61		3.77		3.89		4.02		4.14		4.26		4.38
RS shear, L. I.			439		1,360		2,290		3,360		4,650		6,130		7,850		9,790

[1] Correction factor 0.985 to allow for trapezoidal shape of load.

ATTACK WING

Design of webs

FRONT WEB

Station	1	2	3	4	5	6	7	8
Distance from station 1	0	44	75	107	138	169	200	231
Shear, H. I. pounds	750	2, 250	3, 622	5, 160	6, 945	8, 930	11, 180	13, 560
Depth between flange centroids	5	7. 29	8. 90	10. 57	12. 17	13. 79	15. 39	17. 00
t, required	. 005	. 0112	. 0148	. 0178	. 0207	. 0235	. 0264	. 0290
Recommended gage	. 016	. 0160	. 0160	. 024	. 024	. 032	. 032	. 032

REAR WEB

Shear, L. I. pounds	439	1, 360	2, 290	3, 360	4, 650	6, 130	7, 850	9, 790
Depth, centroids	. 028	3. 71	4. 92	6. 17	7. 31	8. 58	9. 79	11. 00
t, required	. 008	. 0133	. 0169	. 0198	. 0230	. 0257	. 0291	. 0324
Recommended gage	. 016	. 016	. 024	. 024	. 024	. 032	. 032	. 032

$$\text{Depth between centroids, front web}=5+\frac{X}{231}\times 12=7+0.0519X.$$

$$\text{Depth between centroids, rear web}=2+\frac{9}{231}X=2+0.0389X.$$

$$t=\frac{S}{27,500\,d}.$$

ATTACK WING

Design of vertical stiffeners

Station	1	2	3	4	5	6	7	8
Shear, F. W., H. I.	750	2, 250	3, 622	5, 160	6, 945	8, 930	11, 180	13, 560
Depth between centroids	5	7. 29	8. 90	10. 57	12. 17	13. 79	15. 39	17. 00
Rib spacing	21	21	19	19	17	17	15	15
Stiffener spacing	10. 5	10. 5	9. 50	9. 50	8. 5	8. 5	7. 5	7. 5
Load on stiffener	1, 575	3, 240	3, 850	4, 650	4, 850	5, 550	5, 450	5, 980
Area required [1]	. 079	. 162	. 193	. 232	. 242	. 275	. 273	. 299
Thickness section [2]	. 032	. 032	. 040	. 040	. 050	. 050	. 050	. 050
Area section [2]	. 192	. 192	. 240	. 240	. 300	. 300	. 300	. 300
Shear, R. W., L. I.	439	1, 360	2, 290	3, 360	4, 650	6, 130	7, 850	9, 790
Depth between centroids	2	3. 71	4. 92	6. 17	7. 31	8. 58	9. 79	11. 00
Stiffener spacing	5. 25	5. 25	4. 75	4. 75	4. 50	4. 50	4. 50	3. 75
Load on stiffener	1, 150	1, 925	2, 210	2, 590	2, 700	3, 035	3, 610	3, 330
Area required [1]	. 057	. 096	. 111	. 130	. 135	. 1520	. 1805	. 1665
Thickness section [2]	. 020	. 020	. 020	. 024	. 024	. 032	. 032	. 032
Area section [2]	. 120	. 120	. 120	. 144	. 144	. 192	. 192	. 192

[1] Allowable P/A taken at 20,000 pounds per square inch on ¾ by ¾-inch angles riveted to the webs.
[2] 4, ¾ by ¾-inch, angles are considered as compressing a stiffener.

ATTACK WING

Design of upper flange, H. I.

Station	1	2	3	4	5	6	7	8
Moment, H. I. inch-pound	16, 750	111, 800	247, 500	440, 000	705, 500	1, 051, 000	1, 490, 000	2, 030, 000
Depth between centroids inches	6	8. 29	9. 90	11. 57	13. 17	14. 79	16. 39	18
Axial load pounds	2, 790	13, 500	25, 000	38, 000	53, 500	71, 100	91, 000	112, 800
Rib spacing inches				16	16	15	15	15
L/ρ covering				60	60		56	56
Allowable P/A covering				34, 000	34, 000	35, 000	35, 000	35, 000
Total area required square inches			1. 09	1. 46	1. 85	2. 16	2. 52	3. 22
Required area, corrugated				0. 58		1. 52	1. 88	2. 58
Gage required			. 013	. 015	. 022	. 025	. 0336	. 046
Actual gage	. 016	. 016	. 016	. 020	. 024	. 032	. 050	. 050
R/t						21		13. 5
Buckling P/A				26, 000	29, 000	33, 000		39, 000
Actual total area				1. 51	2. 41	2. 41	3. 42	3. 42
Flange angle section		1 No. 3				1 No. 2		

Section No. 2 area of ⅛-inch flange angles=0.62 square inch.
Depth=$6+0.0519X$.
X=distance in inches from station.

Radius of curvature=0.675 inch.
$\rho=0.269$ inch
C=3.
Flat width of sheet=$44\times1.23+2=56$ inches.
Corrugated area=$56\times t$.

ATTACK WING

Design of lower flange, I. F.

Station	1	2	3	4	5	6	7	8
Depth between centroids ... inches	6	8.29	9.90	11.57	13.17	14.79	16.39	18
I. F. moment ... inch-pounds	6,900	46,000	101,200	181,000	291,000	433,000	614,000	835,000
I. F. axial load ... pounds	1,150	5,550	10,200	15,680	22,100	29,100	37,500	46,300
Distribution factor	.695	.702	.703	.704	.707	.711	.714	.716
Axial load, FL flange ... pounds	800	3,860	7,180	11,100	15,600	20,700	26,800	33,200
Axial load, RL flange ... do	350	1,690	3,020	4,580	6,500	8,400	10,700	13,100
	Allowable P/A taken at 25,000 pounds per square inch							
Area required, FL ... square inches	.032	.154	.297	.443	.624	.828	1.07	1.33
Area required, RL ... do	.014	.067	.121	.183	.260	.336	.428	.524
Section FL	1 #10	1 #10	1 #8	1 #8 1 #9	2 #8	2 #8 1 #9	2 #8 1 #9	2 #8 1 #9
Total area, FL ... square inches	.190	.190	.380	.699	.760	1.076	1.076	1.392
Section RL	1 #7	1 #7	1 #12	1 #7 1 #12	1 #7 1 #4	1 #4 1 #12	2 #4	2 #4 1 #11
Total area, RL ... square inches	.114	.114	.146	.260	.360	.360	.428	.526

ATTACK WING

Weight estimate (one-half wing)

Item	Amount	Section and area	Unit weight	Total weight
			Pounds per cubic inch	*Pounds*
Upper flange angles	285 inches	No. 2 0.310	0.1011	8.9
	250 inches	No. 3 0.157	.1011	4.0
Lower flange angles:				
Front	284 inches	No. 8 0.380	.1011	10.8
	190 inches	No. 9 0.316	.1011	6.0
	80 inches	No. 10 0.190	.1011	1.5
	126 inches	No. 4 0.214	.1011	2.7
Rear	34 inches	No. 11 0.098	.1011	0.3
	125 inches	No. 12 0.146	.1011	1.8
	70 inches	No. 7 0.114	.1011	0.8
Total				36.8
Webs:				
Front	100 inches	0.032 x 17.5	.1011	5.7
	62 inches	0.024 x 13.5	.1011	2.0
	95 inches	0.016 x 10.0	.1011	1.5
Rear	100 inches	0.032 x 12	.1011	3.9
	100 inches	0.024 x 8	.1011	2.0
	60 inches	0.016 x 5	.1011	0.5
Total				15.6
L. E. material	250 inches	36 x .020	.1011	18.2
Lower skin	100 inches	48 x .020	.1011	9.6
	84 inches	48 x .076	.1011	6.2
	230 inches	24 x .016	.1011	8.9
	213 inches	18 x .012	.1011	4.6
Total				29.4
Stiffeners:				
Front web	11 at 16 inches	$A=.300$	.1011	5.4
	4 at 12 inches	$A=.240$	.1011	1.2
	4 at 8 inches	$A=.192$	.1011	0.6
Rear web	17 at 11 inches	$A=.192$	.1011	3.6
	8 at 9 inches	$A=.144$	.1011	1.1
	10 at 6 inches	$A=.120$	.1011	0.8
Total				12.7
Wing tip				7
Aileron control rods, cranks, etc				10
Aileron horn, false spar, hinges, etc				6
Miscellaneous fittings, wiring, protective coating, etc				15
Total				31
Corrugated flange:	55 x 80 inches (1 sheet)	$t=.016$ (2½-inch pitch)	.1011	7.0
	55 x 32 inches (1 sheet)	$t=.020$ (2½-inch pitch)	.1011	3.5
	55 x 32 inches (1 sheet)	$t=.024$ (2½-inch pitch)	.1011	4.3
	55 x 32 inches (1 sheet)	$t=.032$ (2½-inch pitch)	.1011	5.6
	55 x 65 inches (1 sheet)	$t=.050$ (2½-inch pitch)	.1011	17.9
Total				37.3
Corrugated cover:	36 x 82 inches (7 sheets)	$t=.012$ (1¼-inch pitch)	.1011	30
Total dead weight less ribs, one-half wing				218
Ribs, 25 per cent of 218 pounds				54.5
Total dead weight, one-half wing				272.5

Area, one-half wing, 152 square feet.
Unit dead weight, 1.79 pounds per square foot.
1.10×dead weight, 1.97 pounds per square foot.

III. TWIN-ENGINED OBSERVATION WING

EFFECT OF NACELLES, GAS TANKS, LANDING GEAR, ETC.

The weight of the engines, nacelles, landing gear, tanks, etc., will arbitrarily be taken at 35 per cent gross weight, and will be considered as acting 85 inches from the center line of the airplane.

The center of gravity of the nacelle group will be considered forward of the front spar a distance sufficient to increase the front spar reaction 15 per cent and cause a −15 per cent reaction on the rear spar.

Lacking detailed design features, the entire wing area from the tip to the side of the fuselage will be considered as effective, that is, no allowances for areas covered by nacelles.

Since this type of airplane will not be subject to the severe diving conditions of the pursuit and attack types, the most severe torque condition will be taken as low incidence.

TWIN-ENGINED OBSERVATION WING

	Per cent
Thickness ratio, section 1	11. 76
Thickness ratio, section 7	18. 46
	6. 70

Thickness ratio, section $0 = 11.76 - \frac{35}{265} \times (18.46 - 11.76) = 11.00$ per cent.

Thickness ratio, section $3 = 11.76 - \frac{67.5}{265} \times (18.46 - 11.76) = 13.47$ per cent.

Chord, station $0 = \frac{11.00}{18.46} \times 67 = 39.9$ inches.

Chord, station $3 = \frac{13.47}{18.46} \times 102.5 = 74.7$ inches.

Area of equivalent wing—

$$A_e = (65 \times 144) + \frac{197.5}{2}(144 + 74.7) + \frac{102.5}{2}(74.7 + 39.9).$$

$$A_e = 9360 + 21596 + 5873 = 36{,}829 \text{ square inches.}$$

Gross weight of airplane = 8,000 pounds.

Estimated wing weight at 1.75 pounds per square foot = 1,000 pounds.

Net weight per wing = (8,000 − 1,000) ½ = 3,500 pounds.

Loading over equivalent wing = W

$$31316W + 0.9 \times 5873W = 3{,}500 \text{ pounds.}$$
$$31316W + 5286W = 3{,}500 \text{ pounds.}$$
$$36602W = 3{,}500 \text{ pounds.}$$
$$W = 0.0956 \text{ pound per square inch.}$$

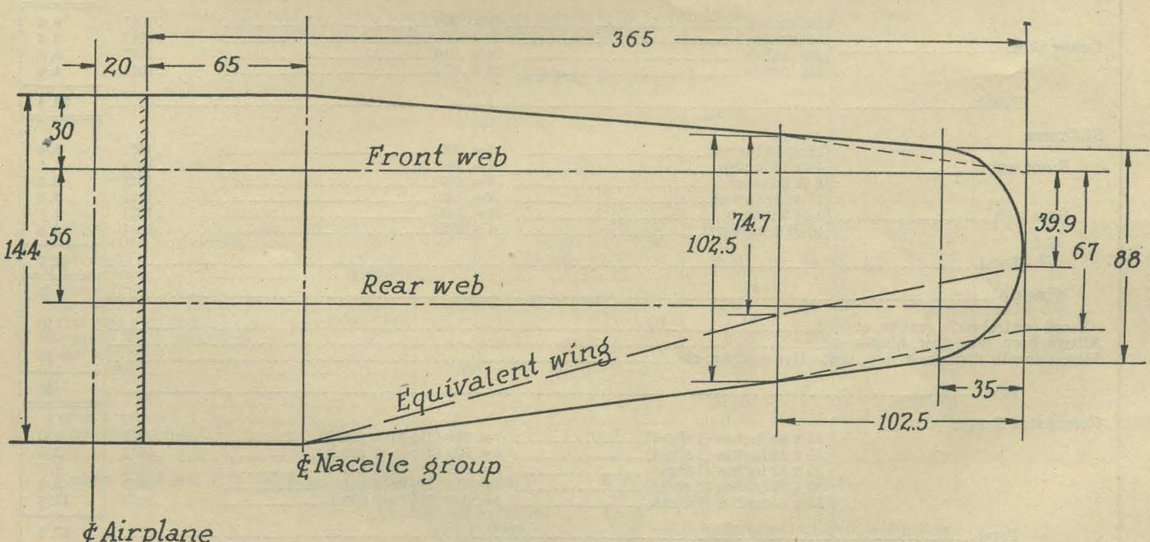

FIGURE 8

TWIN-ENGINED OBSERVATION WING

Airfoil ordinates

Per cent chord	Root: Chord=144 inches at station 7					Tip: Chord=88 inches at station 1				
	Distance along chord	Ordinates				Distance along chord	Ordinates			
		Upper		Lower			Upper		Lower	
		Per cent	Inches	Per cent	Inches		Per cent	Inches	Per cent	Inches
0	0	4.33	6.24	4.33	6.24	0	2.76	2.43	2.76	2.43
1¼	1.8	8.09	11.65	1.62	2.33	1.10	5.15	4.57	1.03	0.90
2½	3.6	9.54	13.70	1.00	1.44	2.20	6.11	5.38	0.63	0.55
5	7.2	11.81	17.00	0.46	0.66	4.40	7.52	6.61	0.28	0.25
7½	10.8	13.58	19.70	0.22	0.32	6.60	8.65	7.61	0.14	0.12
10	14.4	14.85	21.35	0.10	0.14	8.80	9.45	8.31	0.07	0.06
15	21.6	16.60	23.90	0	0	13.20	10.56	9.30	0	0
20	28.8	17.73	24.95	----------	----------	17.60	11.28	9.91	----------	----------
30	43.2	18.46	26.55	----------	----------	26.40	11.76	10.35	----------	----------
40	57.6	17.89	25.70	----------	----------	35.20	11.42	10.05	----------	----------
50	72.0	16.21	23.35	----------	----------	44.00	10.33	9.10	----------	----------
60	86.4	13.83	19.90	----------	----------	52.80	8.81	7.75	----------	----------
70	100.8	11.11	16.60	----------	----------	61.60	7.08	6.23	----------	----------
80	115.2	7.88	11.35	----------	----------	70.40	5.02	4.42	----------	----------
90	129.8	4.31	6.20	----------	----------	79.20	2.72	2.39	----------	----------
95	136.9	2.39	3.45	----------	----------	83.50	1.50	1.32	----------	----------
100	144.0	0.43	0	----------	----------	88.00	0.25	0.22	----------	----------

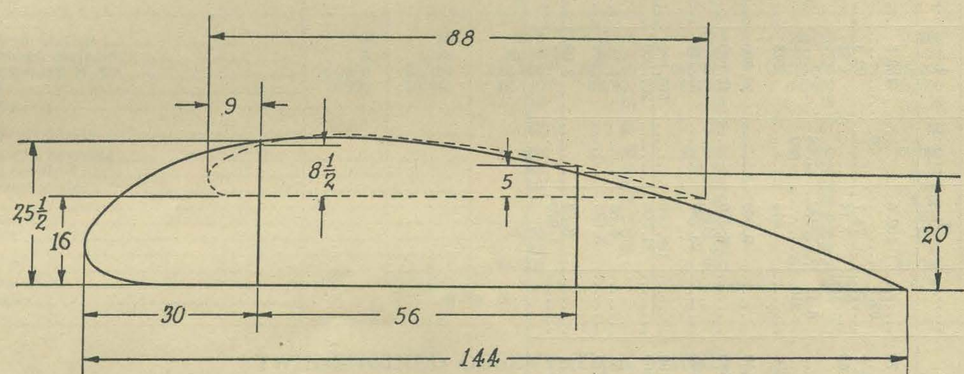

FIGURE 9

TWIN-ENGINED OBSERVATION WING

Load distribution factors

Station	1	2	3	4	5	6	7	8
Distance from station 1	0	35	67.5	117.5	167.5	217.5	265	330
Actual chord	88	95.4	102.5	112.8	123.4	133.9	144	144
Distance LE–CP 31 per cent	27.0	29.5	31.8	34.9	38.2	41.5	44.6	44.6
Distance LE–CP 52 per cent	45.7	49.6	53.4	58.7	64.3	69.7	75.0	75.0
Distance LE–FS	9.0	11.8	14.5	18.2	22.5	26.2	30.0	30.0
Distance LE–RS	65.0	67.8	70.5	74.2	78.5	82.2	86.0	86.0
Distance 31 per cent to RS	38.0	38.3	38.7	39.3	40.3	40.7	41.4	41.4
Distance 52 per cent to FS	36.7	37.8	38.9	40.5	41.8	43.5	45.0	45.0
FS distance factor, H. I. and I. F	.678	.684	.692	.702	.720	.727	.739	.739
RS distance factor, L. I	.656	.675	.695	.723	.746	.777	.804	.804
FS distance factor×LF, H. I	5.76	5.81	5.88	5.96	6.11	6.18	6.28	6.28
RS distance factor×LF, L. I	3.61	3.71	3.82	3.98	4.10	4.27	4.42	4.42

Actual chord$=88+\frac{X}{265}(144-88)=88+0.2115X$ to station 7.

Distance LE to FS$=9+\frac{21}{265}X=9+0.0793X$ to station 7.

TWIN-ENGINED OBSERVATION WING

Basic shears and moments

Station	0		1		2		3		4		5		6		7		8
Distance from tip	0		35		70		102.5		152.5		202.5		252.5		300		365
Distance between station, X		35		35		32.5		50		50		50		47.5		65	
Chord, equivalent wing	39.9		51.8		63.7		74.7		92.3		109.8		127.4		144		144
Running load, pound per inch	3.05		4.33		5.68		7.14		8.81		10.49		12.18		13.78		13.78
Mean running load between station, pound per inch		3.69		5.00		6.41		7.98		9.65		11.33		12.98		13.78	
Load between station, w		130		176		210		402		487		573		622		902	
Total shear, S			130		306		516		918		1,405		1,978		2,600		3,502
Moment SX			0		4,550		9,960		25,800		45,900		70,250		94,000		169,000
Moment $w\frac{X}{2}$			2,270		3,080		3,420		10,050		12,190		14,350		14,150		29,300
Total unit moment			2,270		9,900		23,280		59,130		117,220		201,820		309,970		428,645
H. I. moment			19,300		84,100		198,000		503,500		996,000		1,713,000		2,635,000		3,640,000
I. F. moment			17,950		34,600		81,500		207,000		410,000		705,000		1,085,000		1,498,000
FS distance factor, H. I.			5.76		5.81		5.88		5.96		6.11		6.18		6.28		6.28
FS shear			750		1,778		3,035		5,470		8,590		12,220		16,320		21,980
RS distance factor, H. I.			3.61		3.71		3.82		3.98		4.10		4.27		4.42		4.42
RS shear			470		1,136		1,970		3,655		5,790		8,450		11,500		15,480

CORRECTION DUE TO NACELLE

Weight of nacelle group $= 0.35 \times 3{,}500 = 1{,}225$ pounds.

Correction to BM at station 8:

Decrease in BM $= 1{,}225 \times 65 = 79{,}625$ inch-pounds.

Net BM station $8 = 508{,}270 - 79{,}625 = 428{,}645$ inch-pounds.

Front web shear correction, H. I.:

Shear due to nacelle $= 1{,}225$ pounds.

Total shear, front web, station 7, due to Nacelle $= 1{,}225 \times 1.15 \times 8.5 = 11{,}980$ pounds.

Shear outboard of station 7, front $= 16{,}320$ pounds.

Shear inboard of station 7, front $= 4{,}340$ pounds.

Shear outboard of station 8, front $= 10{,}000$ pounds.

Rear web, L. I.:

Shear due to nacelle $= 0.15 \times 5.5 \times 1{,}225 = 1{,}010$ pounds.

Shear outboard of station 7, rear $= 11{,}500$ pounds.

Rear web, L. I.—Continued.

Shear inboard of station 7, rear $= 12{,}510$ pounds.

Shear outboard of station 8, rear $= 16{,}490$ pounds.

TWIN-ENGINED OBSERVATION WING

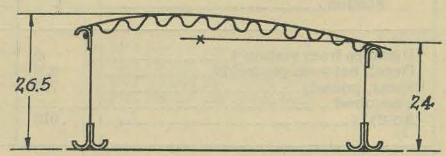

FIGURE 10

Depth between centroids at root $= 24$ inches.

Depth between centroids at tip $= 6$ inches.

Depth between centroids between stations 1 and 7—

$$= 6 + \frac{18}{265} d.$$

$$= 6 + 0.068d.$$

TWIN-ENGINED OBSERVATION WING

Design of upper flange

Station	1	2	3	4	5	6	7	8
Distance from station 1	0	35	67.5	117.5	167.5	217.5	265	
Depth between centroids	6	8.38	10.59	14.00	17.40	20.75	24	24
Bending moment, H. I	19,300	84,100	198,000	503,500	996,000	1,713,000	2,635,000	3,640,000
Axial load	3,220	10,040	18,740	35,900	57,250	82,600	109,500	151,800
Rib spacing			18	18	18	18	15	13
$\frac{L}{\rho}$ covering			67	67	67	67	56	48
Allowable P/A covering			32,400	32,400	32,400	32,400	33,000	37,600
Total area required			.86	1.47	2.34	2.76	3.32	4.04
Area of flange angles			.69	.69	.94	.94	.94	.94
Net area			.17	.78	1.40	1.82	2.38	3.10
Gage required				.0114	.0204	.0266	.035	.045
Actual gage			.0160	.020	.020	.028	.036	.050
R/t			42	33	33	27	19	13.5
Buckling, P/A			23,000		24,400	31,000	33,000	39,000
Total actual area							3.41	4.36
Flange angles	2 No. 14				2 No. 13			

TWIN-ENGINED OBSERVATION WING

Design of lower flanges, I. F.

Station	1	2	3	4	5	6	7	8
Depth between centroids, inches	6	8.38	10.59	14.00	17.40	20.75	24.00	24.00
I. F. moment, inch-pounds	7,950	34,600	81,500	207,000	410,000	705,000	1,085,000	1,498,000
I. F. axial load, pounds	1,325	4,130	8,630	14,800	23,600	34,000	42,500	63,400
FS distance factor, H. I	.678	.684	.692	.702	.720	.727	.739	.739
Axial load, FL flange, pounds	898	2,820	5,960	10,380	17,000	24,700	31,400	46,800
Axial load, RL flange, do	427	1,310	2,670	4,420	6,600	9,300	11,100	16,600
	Allowable stress taken as 25,000 pounds/square inch							
Area required, FL, square inch		.11	.24	.42	.68	.99	1.25	1.87
Area required, RL, do			.11	.18	.254	.37	.45	.67
Total area, FL, do	.114	.114	.46	.46	.690	.975	1.26	1.886
Total area, RL, do	.114	.114	.114	.184	.38	.38	.49	.76
Section FL flange	1 #7	1 #7	1 #7	1 #14 1 #7	1 #14	1 #15 1 #14	2 #15	2 #15 2 #16
Section RL flange	1 #7	1 #7	1 #7	1 #5	1 #8	1 #8	1 #8 1 #6	2 #8

TWIN-ENGINED OBSERVATION WING

Design of webs

FRONT WEB

Station	1	2	3	4	5	6	7	8
Distance from station 1	0	35	67.5	117.5	167.5	217.5	265.0	330.0
Depth between centroids	6.5	8.75	10.83	14.05	17.25	20.45	23.50	23.50
Shear, pounds	750	1,778	3,035	5,470	8,590	12,200	16,320	10,000
t, required	----------	.0074	.0102	.0141	.0181	.0216	.0252	.0155
Actual t	.010	.010	.016	.016	.026	.026	.026	.016

REAR WEB

Station	1	2	3	4	5	6	7	8
Distance from tip	0	35	67.5	117.5	167.5	217.5	265.0	330.0
Depth between centroids	4	5.98	7.82	10.67	13.50	16.30	18.50	18.50
Shear, pounds	470	1,136	1,970	3,655	5,970	8,450	12,500	16,490
t, required	.0047	.0069	.0081	.0125	.0161	.0188	.0245	.0320
Actual t	.010	.010	.010	.016	.016	.024	.024	.032

Front web:

Flanged depth$=65+\frac{17}{265}\times d$ d=distance from station 1.

Thickness, $t=\frac{2S}{55{,}000d}=\frac{S}{27{,}500d}$.

Rear web:

Depth between centroids$=4+\frac{15}{265}d$.

$t=\frac{S}{27{,}500d}$.

TWIN-ENGINED OBSERVATION WING

Design of vertical stiffeners

FRONT BEAM

Station	1	2	3	4	5	6	7	8
Shear, H. I.	750	1,778	3,035	5,470	8,590	12,200	16,320	11,980
Distance from station 1	0	35	67.5	117.5	167.5	217.5	265	330
Depth, centroids	6.50	8.75	10.83	14.05	17.25	20.45	23.50	23.5
Rib spacing	18	18	18	18	18	18	15	13
Stiffener spacing	9	9	9	9	18	18	15	13
Load on stiffener	1,140	1,825	2,510	3,500	8,970	10,740	10,420	6,350
Area required	.045	.073	.100	.140	.360	.469	.418	.254
Section (2 per station)	$\frac{1}{2}\times\frac{1}{2}\times.025$	$\frac{1}{2}\times\frac{1}{2}\times.050$	$\frac{5}{8}\times\frac{5}{8}\times.064$	$\frac{5}{8}\times\frac{5}{8}\times.064$	$1\times1\times.093$	$1\times1\times\frac{1}{8}$	$1\times1\times\frac{1}{8}$	$\frac{3}{4}\times\frac{3}{4}\times.093$
Total area	.050	.10	.160	.160	.382	.50	.50	.279

Allowable stress=25,000.

Depth$=6.5+\frac{17}{265}\times d$.

d=distance from station 1.

The vertical stiffeners will be considered as angles with a buckling strength of 25,000 pounds per square inch. It will be necessary to rivet these stiffeners to the webs in order to place the required number of rivets.

TWIN-ENGINED OBSERVATION WING

Design of vertical stiffeners

REAR BEAM

Station	1	2	3	4	5	6	7	8
Depth between centroids	4	5.98	7.82	10.67	13.50	16.30	18.50	18.50
Shear	470	1,136	1,970	3,655	5,970	8,450	12,500	16,490
Rib spacing	18	18	18	18	18	18	15	13
Stiffener spacing	9	9	9	9	9	9	15	13
Load on stiffener	1,060	1,710	2,270	3,080	3,980	4,670	10,150	11,580
Area required	.042	.069	.091	.123	.160	.187	.406	.463
Section (2 per station)	$\frac{1}{2}\times\frac{1}{2}\times.025$	$\frac{1}{2}\times\frac{1}{2}\times.050$	$\frac{1}{2}\times\frac{1}{2}\times.050$	$\frac{5}{8}\times\frac{5}{8}\times.064$	$\frac{3}{4}\times\frac{3}{4}\times.064$	$\frac{3}{4}\times\frac{3}{4}\times.064$	$1\times1\times\frac{1}{8}$	$1\times1\times\frac{1}{8}$
Total area	.050	.100	.100	.160	.192	.192	.50	.50

Allowable stress=25,000.

TWIN-ENGINED OBSERVATION WING

Weight estimate—one-half wing

Item	Amount	Section	Unit weight	Total weight
Webs:				*Pound*
Rear	55 inches	0.032 x 20	0.1011 pound per cubic inch	3.6
	100 inches	0.024 x 19	0.1011 pound per cubic inch	4.6
	100 inches	0.016 x 13.5	0.1011 pound per cubic inch	2.2
	120 inches	0.010 x 7.5	0.1011 pound per cubic inch	0.9
				11.3
Front	100 inches	0.026 x 22	0.1011 pound per cubic inch	5.8
	185 inches	0.016 x 20	0.1011 pound per cubic inch	6.0
	110 inches	0.010 x 10	0.1011 pound per cubic inch	1.1
				12.9
Flange stiffeners:				
Front web	8 at 24 inches	¾ x ¾ x .093 A=.140	0.1011 pound per cubic inch	2.7
	12 at 24 inches	1 x 1 x ⅛ A=.250	0.1011 pound per cubic inch	7.3
	6 at 19 inches	1 x 1 x .093 A=.191	0.1011 pound per cubic inch	2.2
	10 at 15 inches	⅝ x ⅝ x .064 A=.080	0.1011 pound per cubic inch	1.2
	8 at 12 inches	½ x ½ x .050 A=.050	0.1011 pound per cubic inch	0.5
	8 at 9 inches	½ x ½ x .024 A=.024	0.1011 pound per cubic inch	0.2
				13.1
Rear web	12 at 19.5 inches	1 x 1 x ⅛ A=.250	0.1011 pound per cubic inch	5.9
	10 at 16 inches	¾ x ¾ x .064 A=.091	0.1011 pound per cubic inch	1.5
	4 at 12 inches	⅝ x ⅝ x .064 A=.080	0.1011 pound per cubic inch	0.4
	12 at 8 inches	½ x ½ x .050 A=.050	0.1011 pound per cubic inch	0.5
	8 at 5 inches	½ x ½ x .024 A=.024	0.1011 pound per cubic inch	0.1
				8.4
Upper flange angles; front and rear.	420 inches	No. 13 A=.470	0.1011 pound per cubic inch	20.0
	330 inches	No. 14 A=.345	0.1011 pound per cubic inch	11.5
				31.5
Lower flange angles	320 inches	No. 15 A=.630	0.1011 pound per cubic inch	20.4
	55 inches	No. 16 A=.313	0.1011 pound per cubic inch	1.8
	150 inches	No. 14 A=.345	0.1011 pound per cubic inch	5.2
	270 inches	No. 7 A=.114	0.1011 pound per cubic inch	3.1
	265 inches	No. 8 A=.380	0.1011 pound per cubic inch	10.0
	50 inches	No. 5 A=.184	0.1011 pound per cubic inch	1.0
				41.5
Corrugated upper flange	60 inches	0.050 x 58 x 1.23	0.1011 pound per cubic inch	21.7
	50 inches	0.036 x 58 x 1.23	0.1011 pound per cubic inch	13.0
	50 inches	0.028 x 58 x 1.23	0.1011 pound per cubic inch	10.1
	110 inches	0.020 x 58 x 1.23	0.1011 pound per cubic inch	15.9
	95 inches	0.016 x 58 x 1.23	0.1011 pound per cubic inch	11.0
				71.7
Nose covering	330 inches	0.020 x 48	0.1011 pound per cubic inch	33.5
Bottom skin	330 inches	0.012 x 100	0.1011 pound per cubic inch	14.6
Upper corrugated skin	330 inches	0.012 x 100	0.1011 x 1.23	18.0
Ribs	23 inches		2-pound average	46.0
Nose ribs	46 inches		0.5-pound average	23.0
Wing tip	12,000 square inches	0.020	0.1011 pound per cubic inch	25.0
Controlrods, cranks, cables, etc				15
Aileron, spar, structure, etc				10
Miscellaneous fittings				15

TWIN-ENGINED OBSERVATION WING

Weight less ribs .... 321.5 pounds.
Ribs at 25 per cent of 321.5 .... 80.5 pounds.

Dead weight .... 402.0 pounds.

Area, half wing .... 289 square feet.
Unit weight .... 1.39 pounds per square foot.
1.1 × unit weight .... 1.53 pounds per square foot.

IV. TRANSPORT WING

Thickness ratio, chord $CD = 11.76 + \frac{33}{336}(18.46 - 11.76) = 12.42$.

Thickness ratio, chord $AB = 11.76 - \frac{70}{336} \times (6.70) = 10.36$

Equivalent chord $C'D' = \frac{12.42}{18.46} \times 103 = 69.4$ inches.

Equivalent chord $A'B' = \frac{10.36}{18.46} \times 63 = 35.3$ inches.

Area of section $AB'CD' = \frac{69.4 + 35.3}{2} \times 103 = 5{,}390$ square inches.

Area of section $CD'EF = \frac{69.4 + 170}{2} \times 303 = 36{,}300$ square inches.

Total .... 41,690 square inches.

	Pounds
Gross weight of airplane	12, 500
Estimated wing weight	1, 500
Net weight on wing	11, 000

$$36{,}300 W_d + 0.9 \times 5{,}390 W_d = 5{,}500$$
$$36{,}300 W_d + 4{,}850 W_d = 5{,}500$$
$$W_d = 1{,}337 \text{ pounds per square inch.}$$

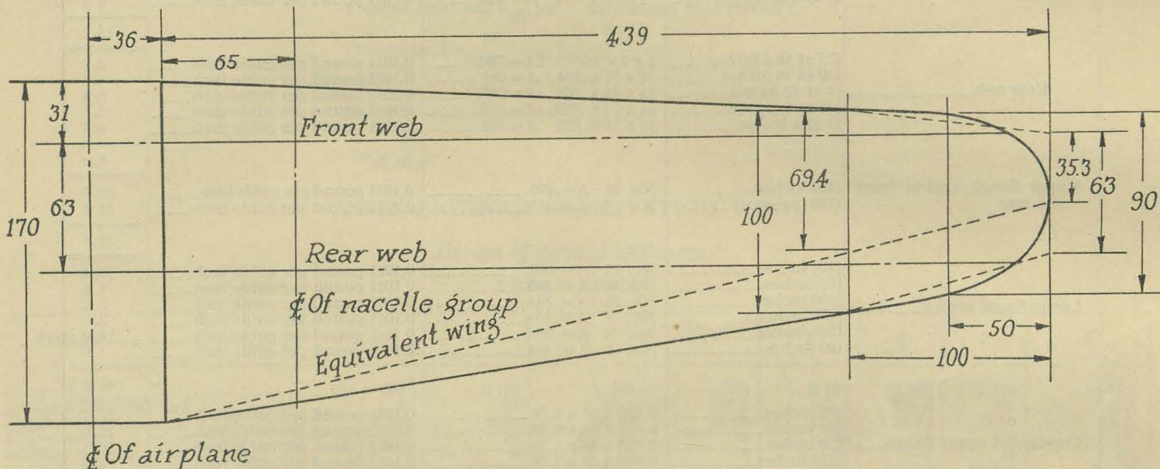

FIGURE 11

TRANSPORT WING

Airfoil ordinates

Per cent chord	Root: Chord=170 inches					Tip: Chord=90 inches				
	Distance along chord	Ordinates: Upper		Ordinates: Lower		Distance along chord	Ordinates: Upper		Ordinates: Lower	
		Per cent	Inches	Per cent	Inches		Per cent	Inches	Per cent	Inches
0	0	4.33	7.36	4.33	7.36	0	2.76	2.48	2.76	2.48
1¼	2.12	8.09	13.75	1.62	2.75	1.125	5.15	4.63	1.03	0.93
2½	4.25	9.54	16.21	1.00	1.70	2.25	6.11	5.50	0.63	0.57
5	8.50	11.81	20.10	0.46	0.78	4.50	7.52	6.75	0.28	0.25
7½	12.75	13.58	23.05	0.22	0.37	6.75	8.65	7.78	0.14	0.12
10	17.00	14.85	25.25	0.10	0.17	9.00	9.45	8.50	0.07	0.06
15	25.50	[illegible]	[illegible]	----------	----------	13.50	10.56	9.50	----------	----------
20	34.00	17.73	30.15	----------	----------	18.00	11.28	10.15	----------	----------
30	51.00	18.46	31.35	----------	----------	27.00	11.76	10.59	----------	----------
40	68.00	17.89	30.40	----------	----------	36.00	11.42	10.29	----------	----------
50	85.00	16.21	27.55	----------	----------	45.00	[illegible]	[illegible]	----------	----------
60	102.00	13.83	23.50	----------	----------	54.00	8.81	7.83	----------	----------
70	119.00	11.11	18.90	----------	----------	63.00	7.08	6.36	----------	----------
80	136.00	7.88	13.40	----------	----------	72.00	5.02	4.51	----------	----------
90	153.00	4.31	7.34	----------	----------	81.00	2.72	2.45	----------	----------
100	170.00	0.43	0.73	----------	----------	90.00	0.25	0.22	----------	----------

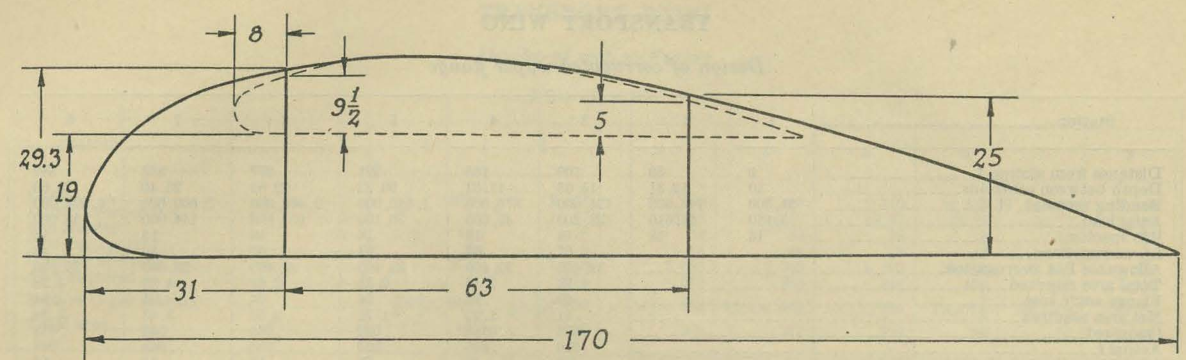

FIGURE 12

TRANSPORT WING

Spar distribution factors

Station	1	2	3	4	5	6	7	8
Distance from station 1	0	50	109	165	221	277	333	389
Actual chord	90	100	112.4	123.9	135.5	147	158.5	170
Distance LE-CP 31 per cent	27.9	31	34.90	38.40	42.00	45.60	49.10	52.7
Distance LE-CP 52 per cent	46.8	52	58.50	64.30	70.50	76.50	82.50	88.5
Distance LE-FS	8	10.96	14.45	17.75	21.05	24.38	27.68	31
Distance LE-RS	71	73.96	77.45	80.75	84.05	87.38	90.68	94
Distance 31 per cent to RS	43.1	42.96	42.55	42.35	42.05	41.78	41.58	41.3
Distance 52 per cent to FS	38.8	41.04	44.1	46.55	49.45	52.20	54.82	57.5
FS factor, H. I. and I. F	.684	.682	.676	.672	.668	.664	.660	.656
RS factor, L. I	.616	.652	.700	.740	.785	.829	.871	.914
FS factor×5.5	3.76	3.75	3.72	3.69	3.67	3.65	3.63	3.61
RS factor×3.5	2.16	2.28	2.45	2.59	2.75	2.90	3.05	3.20

TRANSPORT WING

Design of webs

FRONT WEB, H. I.

Station	1	2	3	4	5	6	7	8
Distance from station 1 (d)	0	50	109	165	221	277	333	389
Depth between centroids	8	10.57	13.61	16.50	19.37	22.25	25.12	28.00
Shear, pounds	862	2,175	4,260	6,600	9,350	12,460	16,000	19,850
t, required	.0039	.0075	.0138	.0145	.0175	.0198	.0232	.0258
Actual *t*	.010	.010	.016	.016	.020	.020	.028	.028

REAR WEB, L. I.

Shear, pounds	495	1,350	2,800	4,630	6,740	9,900	13,450	17,600
Centroid depth	4	6.57	9.61	12.50	15.37	18.25	21.12	24.00
t required	.0045	.0075	.0105	.0135	.016	.0197	.0250	.0284
Actual *t*	.010	.010	.016	.016	.020	.020	.028	.028

Front web:

$$\text{Depth between centroids}=8+\frac{20}{389}\times d=8+0.0515d.$$

$$t=\frac{S}{27{,}500d}.$$

Rear web:

$$\text{Depth between centroids}=4+0.0515d.$$

$$t=\frac{S}{27{,}500d}.$$

TRANSPORT WING

Design of corrugated upper flange

Station	1	2	3	4	5	6	7	8
Distance from station 1	0	50	109	165	221	277	333	389
Depth between centroids	10	12.31	15.05	17.63	20.22	22.82	25.40	28.00
Bending moment, H. I	31,500	143,000	424,000	876,000	1,540,000	2,460,000	3,660,000	[1] 4,408,000
Axial load	3,150	11,610	28,200	49,600	76,100	107,800	144,000	158,000
Rib spacing	18	18	18	18	18	18	15	13
L/ρ corrugations			67	67	67	67	56	48
Allowable P/A corrugation			32,400	32,400	32,400	32,400	33,000	36,800
Total area required			1.23	2.16	2.65	3.61	4.37	4.28
Flange angle area			.69	.94	.94	.94	.94	.94
Net area required			.51	1.22	1.71	2.67	3.43	3.34
t required			.005	.0158	.022	.034	.043	.043
Actual t			.016	.016	.024	.036	.048	.048
R/t			42	42	28	19	14	14
Buckling stress			23,000	23,000	28,800	34,600	39,000	39,000
Flange angles		2 No. 14				2 No. 13		

[1] Decrease due to nacelle weight.

Depth between centroids $=10+\frac{18}{389}d=10+0.463d$.

$R=0.675$ inch. $\rho=0.269$ inch.

$t=\frac{\text{net area}}{63\times1.23}=\frac{A}{77.5}$

TRANSPORT WING

Design of lower flanges, I. F.

Station	1	2	3	4	5	6	7	8
Depth between centroids	10	12.31	15.05	17.63	20.22	22.82	25.40	28.00
Bending moment, I. F	14,300	62,500	19,300	39,800	700,000	1,120,000	1,668,000	[1] 2,055,000
Axial load, I. F	1,430	5,060	12,800	22,600	34,600	49,000	65,500	73,300
FS distribution factor	.684	.682	.676	.672	.668	.664	.660	.656
FS axial load	978	3,450	8,660	15,200	23,100	32,300	43,200	48,100
RS axial load	452	1,610	4,140	7,400	11,500	16,700	22,300	25,200
Allowable stress, 25,000 pounds per square inch								
Area required, FS	.04	.14	.35	.61	.925	1.29	1.72	1.93
Area required, RS	.02	.06	.16	.30	.46	0.67	0.90	1.01
Section FL	1 #12	1 #12	1 #8	1 #15	1 #15 1 #16	2 #19	2 #19 1 #18	2 #19 2 #18
Area, FL	.146	.146	.38	.63	.94	1.36	1.79	2.09
Section RL	1 #6	1 #6	1 #5	1 #8	1 #13	1 #19	1 #19 1 #16	1 #15 1 #18
Area, RL	.31	.31	.31	.38		.68	.99	1.06

[1] Decrease due to nacelle weight.

TRANSPORT WING

Corrections for nacelle loads

Weight of nacelle group taken as 35 per cent gross weight.

Weight of nacelle group $\frac{0.35}{2}\times12{,}500=2{,}180$ pounds.

The effect of the nacelle group, which will be considered as acting 65 inches from the fuselage fittings, is to reduce the beam-bending moments in high and low incidence, and to increase the rear spar shear, while the front spar shear is decreased. The mass of the nacelles will be considered as so located as to cause the rear spar shear at the nacelle to increase 15 per cent of the nacelle weight, while the front spar shear decreases 115 per cent of the nacelle weight.

Decrease in moment at wing weight, H. I. $=2{,}180\times65\times5.5=782{,}000$ inch-pounds.

Moment at root, H. I $=5{,}190{,}000-782{,}000=4{,}408{,}000$.

Decrease in moment, I. F $=2{,}180\times65\times2.5=355{,}000$.

Moment at root, I. F. $=2{,}360{,}000-355{,}000=2{,}005{,}000$.

The front web will be assumed to carry its full shear in order to approximate landing shears.

Rear web shear due to nacelle, L. I. $=0.15\times2{,}180\times3.5=1{,}150$ pounds.

This will act at stations 7 and 8.

TRANSPORT WING

Design of web stiffeners

FRONT WEB

Station	1	2	3	4	5	6	7	8
Shear	862	2,175	4,260	6,600	9,350	12,460	16,000	19,850
Depth, centroids	8	10.57	13.61	16.50	19.37	22.25	25.12	28.00
Rib spacing	18	18	18	18	18	18	15	13
Stiffener spacing	9	9	18	18	18	18	15	13
Load on stiffener	970	1,850	5,625	7,200	8,700	10,100	9,560	9,220
Area required		.074	.275	.288	.348	.404	.372	.369
Section (2 per station)	$\frac{1}{2}\times\frac{1}{2}\times.050$	$\frac{1}{2}\times\frac{1}{2}\times.050$	$\frac{3}{4}\times\frac{3}{4}\times.093$	$1\times1\times.093$	$1\times1\times.093$	$1\times1\times\frac{1}{8}$	$1\times1\times\frac{1}{8}$	$1\times1\times\frac{1}{8}$
Total area	.10	.10	.279	.372	.372	.50	.50	.50

REAR WEB

Shear	495	1,350	2,800	4,630	6,740	9,900	14,600	18,750
Depth, centroids	4	6.57	9.61	12.50	15.37	18.25	21.12	24.00
Rib spacing	18	18	18	18	18	18	15	13
Stiffener spacing	9	9	9	9	18	18	15	13
Load on stiffener	1,100	1,850	2,620	3,340	7,900	9,760	10,400	10,150
Area required	.045	.074	.105	.134	.314	.39	.415	.406
Section (2 per station)	$\frac{1}{2}\times\frac{1}{2}\times.050$	$\frac{1}{2}\times\frac{1}{2}\times.050$	$\frac{5}{8}\times\frac{5}{8}\times.064$	$\frac{5}{8}\times\frac{5}{8}\times.064$	$1\times1\times.093$	$1\times1\times\frac{1}{8}$	$1\times1\times\frac{1}{8}$	$1\times1\times\frac{1}{8}$
Total area	.10	.10	.16	.16	.372	.50	.50	.50

Allowable stress, 25,000 pounds per square inch.

TRANSPORT WING

Investigation of torque at wing root

Consider an eccentricity of 0.25 per cent M. A. C. in the low incidence condition.

M. A. C. = 103 inches

Torque at root $= 0.25\times130\times5{,}500\times3.5 = 626{,}000$ inch-pounds.

Assume that all the torque is to be carried by the box portion.

Area of box section at root $= 28\times63 = 1{,}765$ square inches, approximately.

Using the general approximate equation

$$T=\frac{Q}{2At}$$

t = shear stress at any point where skin thick = t.

Q = torque.

A = mean area of section.

in corrugated sheet

$$T=\frac{626{,}000}{1{,}765\times.048}=7{,}400 \text{ pounds per square inch,}$$

which is safe.

Solving for the minimum skin thickness on the lower surface

$$t=\frac{626{,}000}{1{,}765\times27{,}500}=0.013 \text{ inch;}$$

therefore 0.016 material will present a safe margin.

TRANSPORT WING

Weight estimate—one-half wing

Item	Amount	Section	Unit weight	Total weight
	Inches		*Pounds per cubic inch*	*Pounds*
Upper flange angles	520	No. 13 A=.47	0.1011	25.0
	430	No. 14 A=.345	.1011	14.8
				39.8
Lower flange angles	464	No. 19 A=.68	.1011	31.5
	184	No. 18 A=.432	.1011	8.0
	112	No. 15 A=.63	.1011	7.1
	112	No. 16 A=.313	.1011	3.5
	172	No. 8 A=.38	.1011	6.6
	160	No. 12 A=.146	.1011	2.2
	56	No. 13 A=.47	.1011	2.6
	60	No. 5 A=.184	.1011	1.1
	110	No. 6 A=.098	.1011	1.1
				63.7
Corrugated upper flange	120	77.5 x .048	.1011	44.0
	56	77.5 x .036	.1011	15.6
	56	77.5 x .024	.1011	10.5
	143	77.5 x .016	.1011	18.0
				88.1
Rear web	120	22 x .028	.1011	7.5
	112	18 x .020	.1011	4.1
	112	13 x .016	.1011	2.4
	100	7 x .010	.1011	0.7
				14.7
Front web		$\frac{14.7}{2}\left(\frac{8}{4}+\frac{28}{24}\right)=$	.1011	23.2
Stiffeners:				
Rear web	440	1 x 1 x ⅛ A=.25	.1011	11.2
	120	1 x 1 x .093 A=.186	.1011	2.2
	280	⅝ x ⅝ x .064 A=.08	.1011	2.2
	130	½ x ½ x .05 A=.05	.1011	0.8
				16.4
Front web	488	1 x 1 x ⅛ A=.25	.1011	12.4
	230	1 x 1 x .093 A=.186	.1011	4.3
	90	¾ x¾ x .093 A=.14	.1011	1.3
	220	½ x ½ x .050 A=.05	.1011	1.1
				19.1
Lower covering	475	70 x .016	.1011	53.5
	475	50 x .024	.1011	57.0
	475 x 1.23	70 x .12	.1011	51.0
				161.5
Wing tip, (partially included in skin estimates)				10
Control rods, cables, etc				20
Aileron, spar, structure, etc				15
Miscellaneous fittings				20
				55
Total weight less ribs				485.5
Ribs at 25 per cent of 485.5 pounds				121.5
				607.0
Area, half wing, 427 square inches. Unit weight, 1.42 pounds per square inch. 1.1 × 1.42, 1.56 pounds per square inch.				

TRANSPORT WING

Shears and moments

Station	0		1		2		3		4		5		6		7		8
Distance from station 2							59		115		171		227		283		339
Chord, equivalent wing	35.3		52.4		69.4		86.9		103.5		120		136.7		153.3		170
Distance between station, X		50		50		59		56		56		56		56		56	
Running load, pounds per inch	[1] 3.78		[1] 6.30		9.26		11.60		13.80		16.02		18.22		20.50		22.70
Mean running load, W		5.04		7.78		10.43		12.70		14.91		17.12		19.36		21.60	[2]
Load between station, WX		229		353		560		645		760		870		985		1,097	
Shear $=\Sigma WX$			229		582		1,142		1,787		2,547		3,417		4,403		5,500
Moment $W\frac{X^2}{2}$		5,730		8,830		16,500		18,050		21,250		24,350		27,600		30,750	
Moment SX					11,440		34,900		64,100		100,000		142,700		191,000		247,000
Total moment			5,730		26,000		77,050		159,200		280,450		447,500		666,100		943,850
H. I. moment			31,500		143,000		424,000		876,000		1,540,000		2,460,000		3,660,000		5,190,000
I. F. moment			14,300		62,500		193,000		398,000		700,000		1,120,000		1,668,000		2,360,000
FS distance factor			3.76		3.74		3.72		3.69		3.67		3.65		3.63		3.61
FS shear			862		2,175		4,260		6,600		9,350		12,460		16,000		19,850
RS distance factor			2.16		2.28		2.45		2.59		2.75		2.90		3.05		3.20
RS shear			495		1,350		2,800		4,630		6,740		9,900		13,450		17,600

[1] 0.8 tip loading.
[2] Factor of 0.907 used to bring shear to 5,500 pounds.